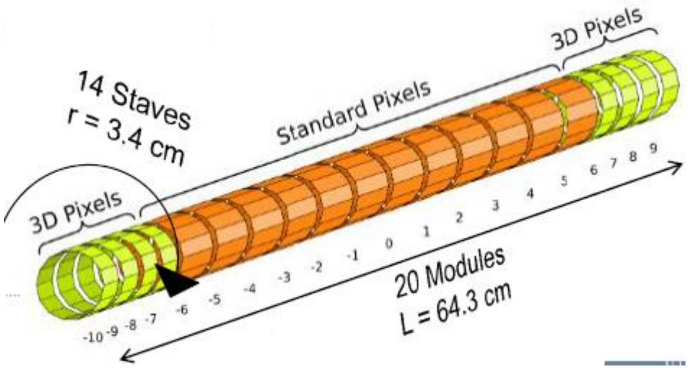
Status of the Pixel-Cluster Counting Luminosity Measurement

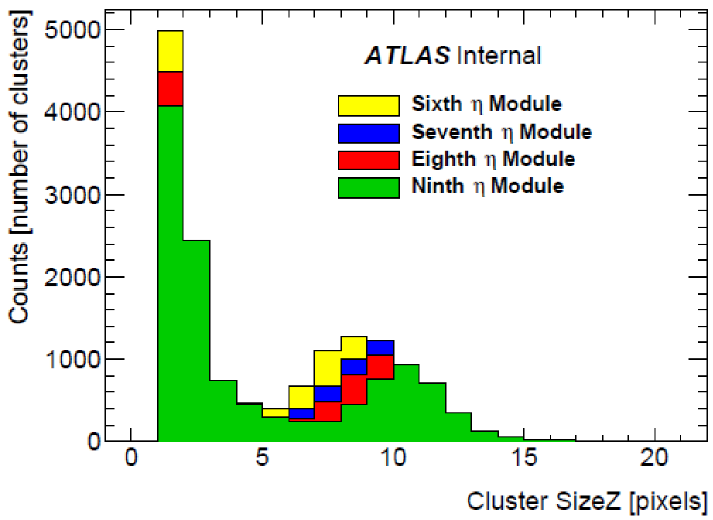
Lina Galtieri, Maurice Garcia-Sciveres,
Simone Pagan Griso,
Wm. Patrick McCormack, Peilian Liu

May 26, 2017

Pixel Cluster Counting (PCC) in IBL

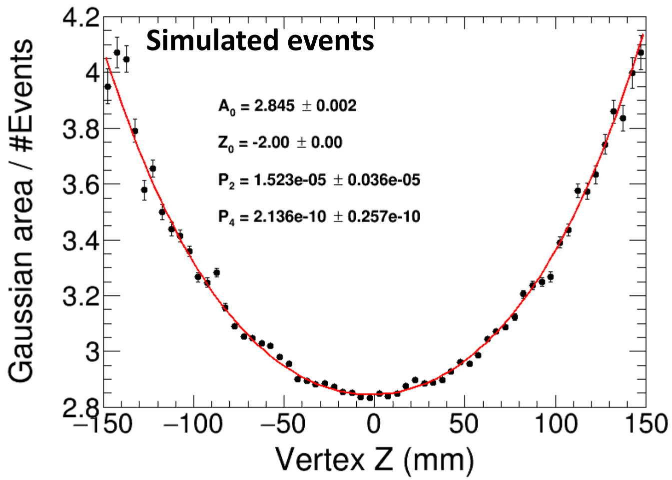
- The luminosity is proportional to the number of pixel clusters
- Only count the clusters in 3D modules in IBL to get better S-B separation





Dependence on beamspot shape

- The number of pixels in the 3D sensors in IBL depends on the interaction location ← different acceptance



(interaction position x and y are well constrained)

- The number of pixel clusters in all 3D sensors produced by the interaction at Z
  $= A_0 * (1 + p_2 * (z - z_0)^2 + p_4 * (z - z_0)^4)$

Obtained with the study of simulated single interaction events

(z_0 is the IBL center. $z_0 = -2\text{mm}$ in the simulated samples)

- The interaction vertices density in Z is Gauss(Z; $\boldsymbol{\mu_z}, \boldsymbol{\sigma_z}$) ~ beamspot
- The total number of pixel clusters produced by all interactions

$$= \int A_0 * (1 + p_2 * (z - z_0)^2 + p_4 * (z - z_0)^4) * Gauss(z, \mu_z, \sigma_z) dz$$

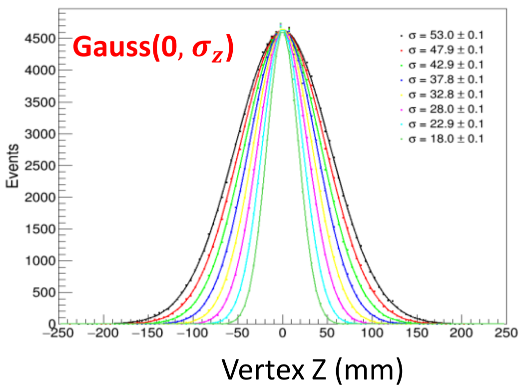
$$= \boldsymbol{A_0 * \left[1 + p_2 * \left((\mu_z - z_0)^2 + \sigma_z^2\right) + p_4 * \left((\mu_z - z_0)^4 + 6\sigma_z^2(\mu_z - z_0)^2 + 3\sigma_z^4\right)\right]}$$

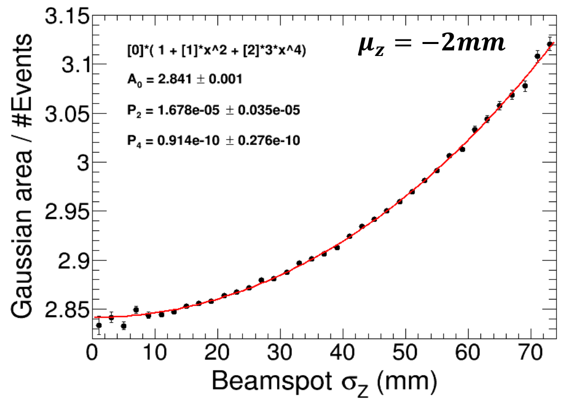
❖ The obtained area should be corrected to be A_0 which only depends on $< \mu >$

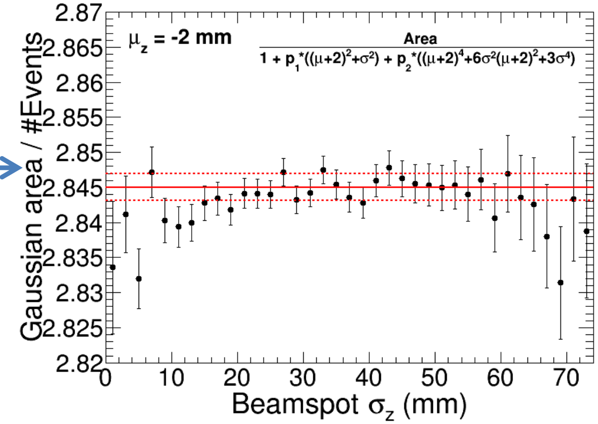
Correction of the beamspot shape dependence

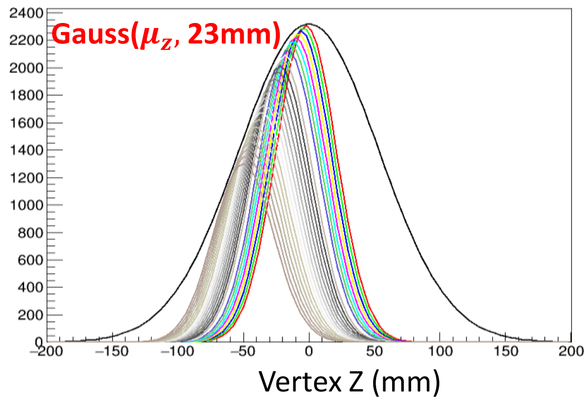
– The area obtained with beamspot ~ $Gauss(\mu_z, \sigma_z)$ should be corrected via:

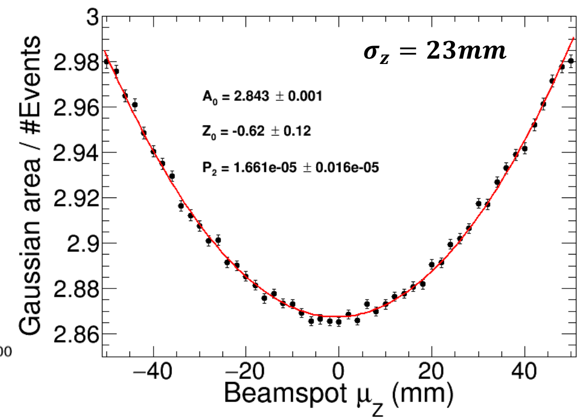
$$\boldsymbol{A_0 = \frac{Area}{1+p_2*\left((\mu_z-z_0)^2+\sigma_z^2\right)+p_4*\left((\mu_z-z_0)^4+6\sigma_z^2(\mu_z-z_0)^2+3\sigma_z^4\right)}}$$

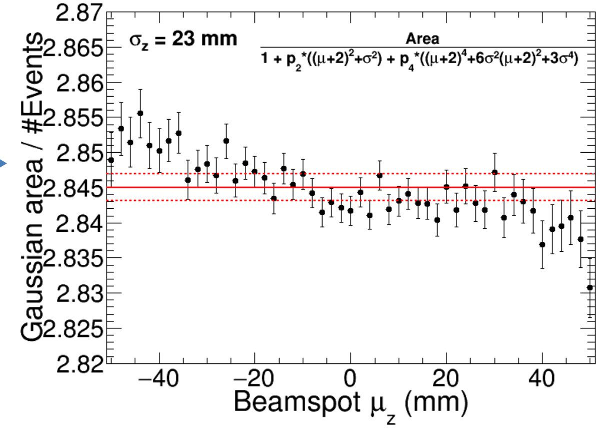








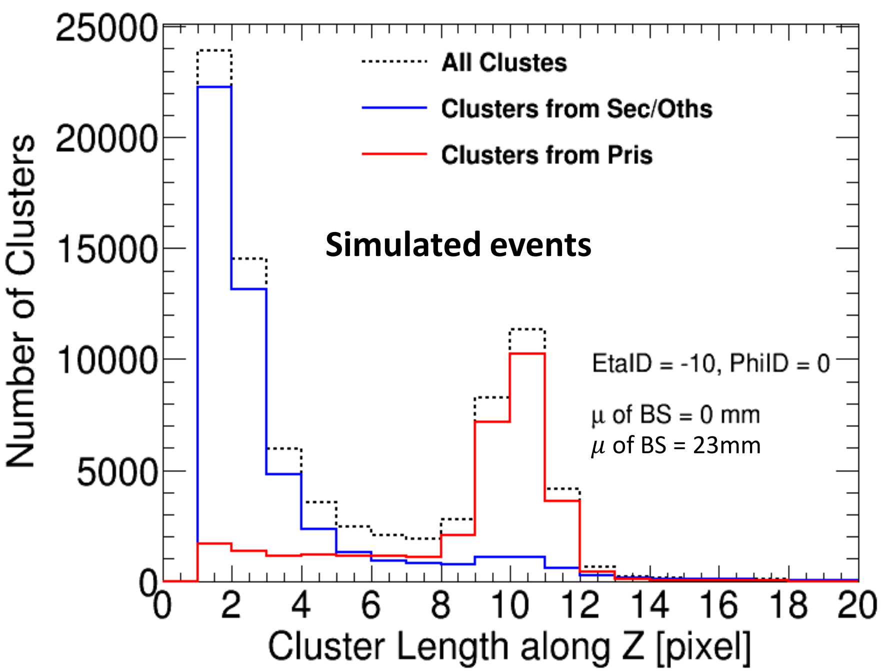




❖ After the correction, the number of clusters obtained from any beamspot shape is consistent with the expected A_0

Counting truth →Fitting

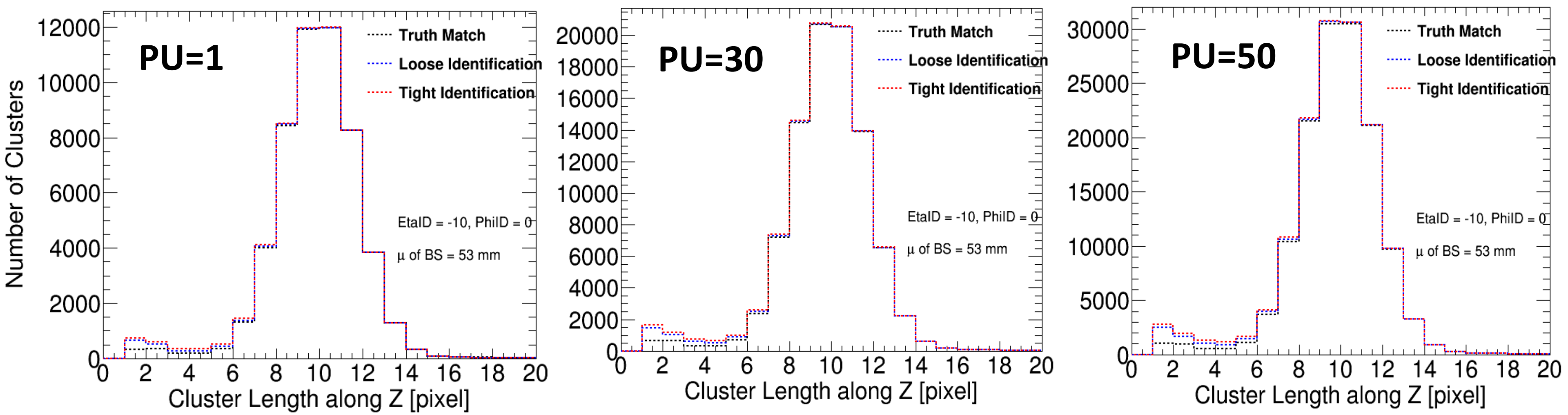
- The study of MC is performed by counting the clusters from primary particles
- The number of clusters only could be obtained by fitting in the real data due to the bkgs
  - Secondary particles are from the interaction of primaries with the material(barcode>200000)
    - Others: some secondary particles do not have truth information stored for space reasons.
  - "Afterglow": delayed tails of the particle cascade produced in the detector material (not in MC)



- The cluster length of clusters from primary particles (barcode<200000) are supposed to be a Gaussian
  - Gaussian shape of beamspot
- ✓ Flat tail of the clusters from primary particles
  - Clusters on the module edge
  - Broken clusters
- ❖ Easy to know which clusters are on the edge, but *how to identify the broken clusters*?

Identification of broken clusters

- **Truth Match**
  - There are other clusters from the same matched truth particles
- **Tight (Loose) Identification independent of truth information**
  - There are other clusters with one pixel gap along Z relative to this cluster, and some of their hits are in the same (or adjacent) rows



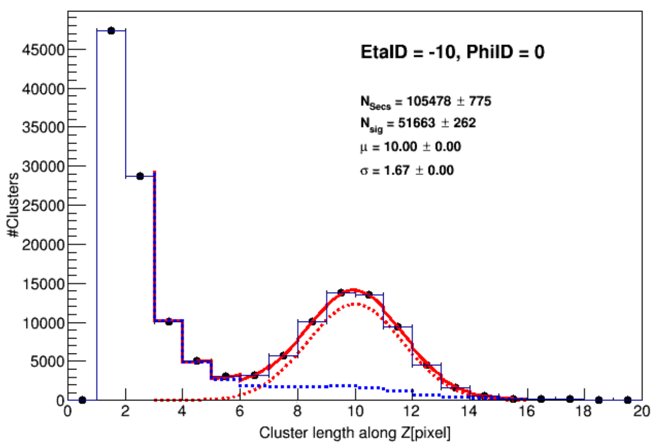
✓ Simulated events, Beamspot $\sim \mu_z = 0, \sigma_z = 53mm$

❖ **This identification method works even for high pile-up events**
But there are still some clusters in flat tail. Gaussian shape could give it a good description?

How to describe the backgrounds?

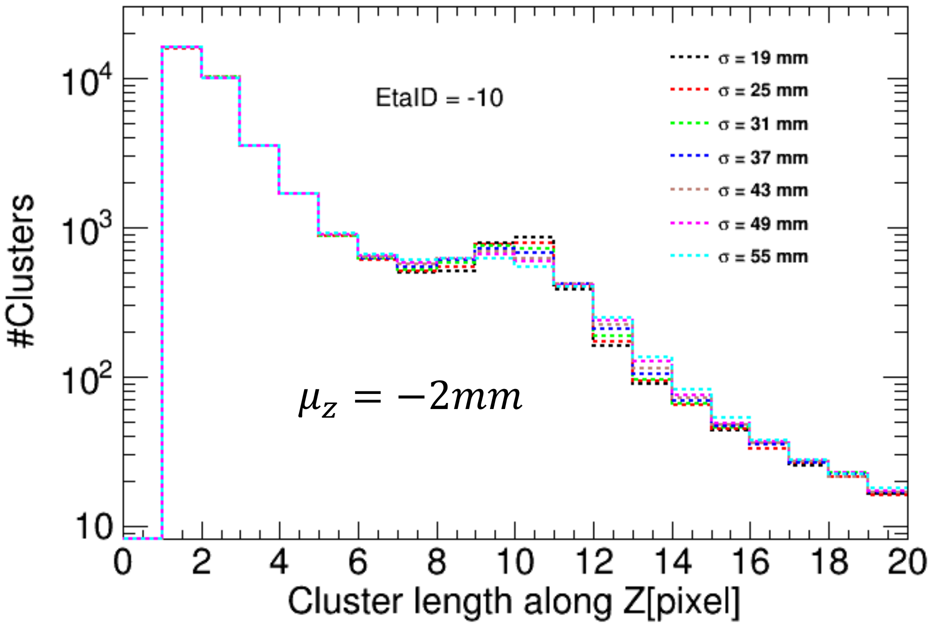
- Backgrounds source
  - Secondary clusters from the interaction of primaries with the material
    - Template derived from MC
  - "Afterglow": delayed tails of the particle cascade produced in the detector material
    - Exponentially falling
    - No simulation of the exponential afterglow in MC

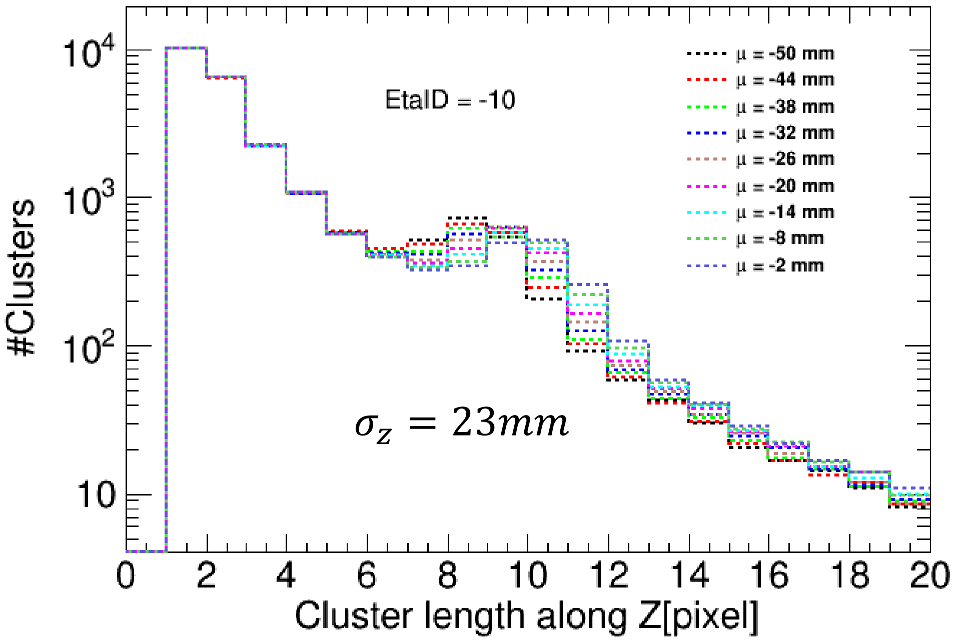
- How to get the template of the secondary clusters
  - All clusters except for those from the primary particles
  - The template of each eta ring is averaged over 14 modules in the same ring



- Fit to MC
  - Gaussian + BkgTemplate

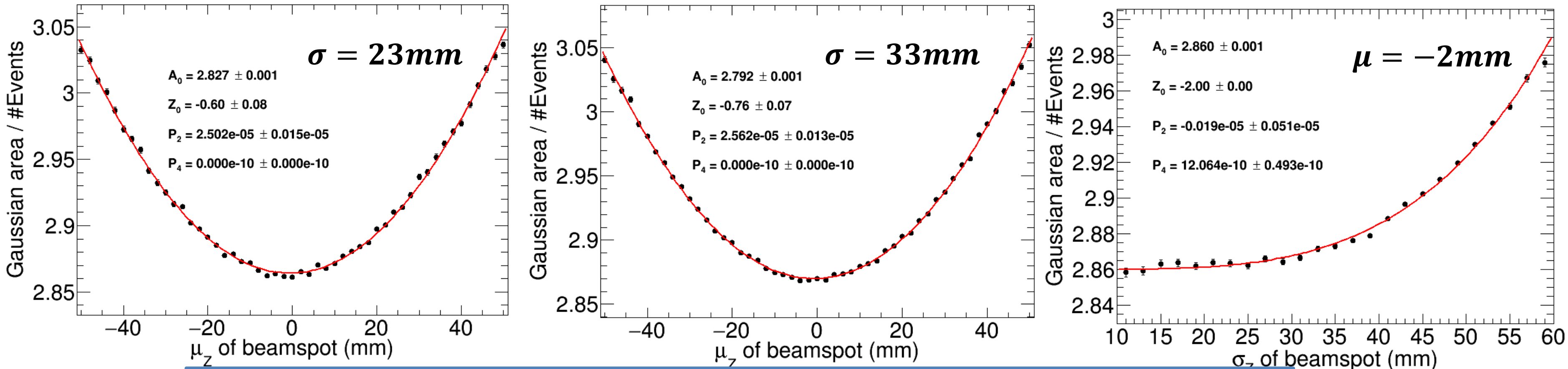
MC-derived template depends on the beamspot shape?





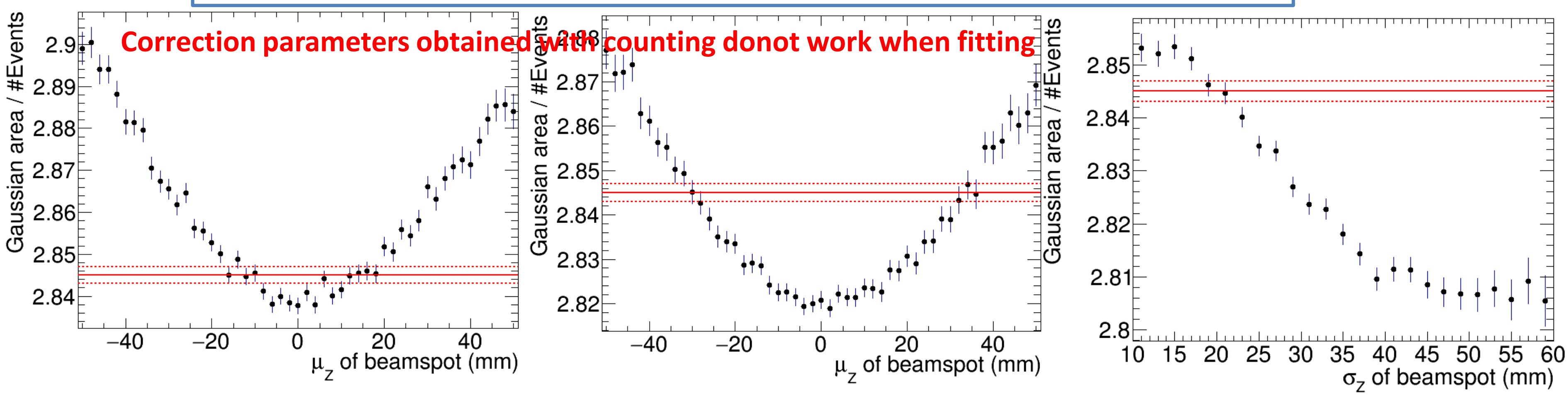
- The template slightly depends on the beamspot position and width

Could Gaussian + BkgTemplate well describe MC?



$$A_0 * \left[1 + p_2 * \left((\mu_z - z_0)^2 + \sigma_z^2\right) + p_4 * \left((\mu_z - z_0)^4 + 6\sigma_z^2(\mu_z - z_0)^2 + 3\sigma_z^4\right)\right]$$

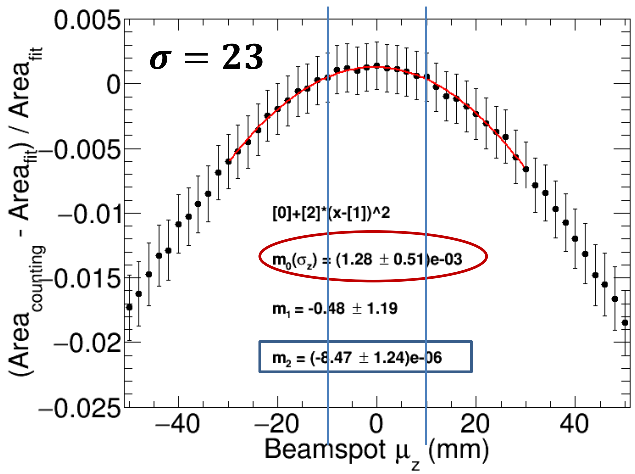
Correction parameters obtained with counting donot work when fitting

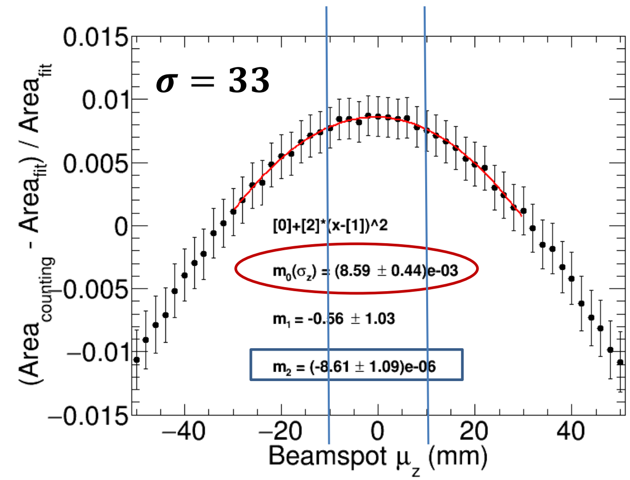


- Expected area (A_0) and correction parameters (p_2, p_4) obtained with different samples are not consistent
  - Due to the BS shape dependence of the BkgTemplate or the flat tail of signal?
  - Deviation of the fit result relative to counting result $\frac{Area_{counting} - Area_{fit}}{Area_{fit}}$

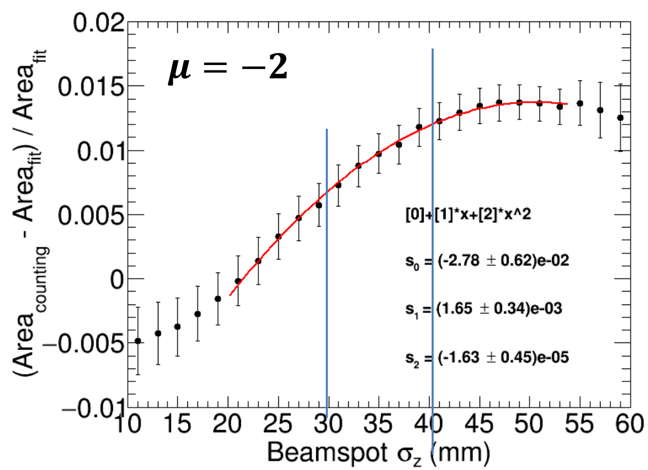
$$\frac{Area_{counting} - Area_{fit}}{Area_{fit}}$$

- $\frac{Area_{counting} - Area_{fit}}{Area_{fit}} = m_0(\sigma_z) + m_2(\mu_z - z_0)^2$





- $m_0(\sigma_z) = s_0 + s_1\sigma_z + s_2\sigma_z^2$



$m_0(\sigma_z = 23) = 1.38e-03$
$m_0(\sigma_z = 33) = 8.72e-03$

❖ $\boldsymbol{Area_{counting} = Area_{fit}(1 + s_0 + s_1\sigma_z + s_2\sigma_z^2 + m_2(\mu_z - z_0)^2)}$

- $m_0(\sigma_z)$ obtained in the top two plots are consistent with those in the bottom plot
- m_2 obtained in the top two plots are consistent with each other

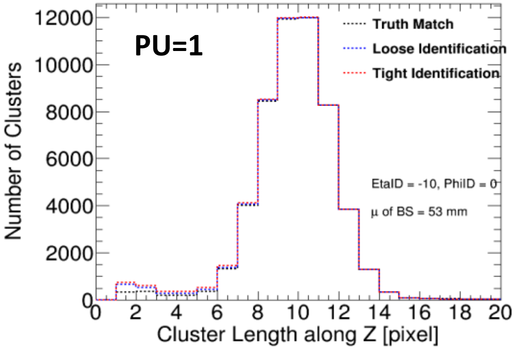
Preparation work before the study of real data

- To validate the correction in real data
  - Need to filter out the cluster on module edge and broken clusters
  - “eta_pixel_index” and “phi_pixel_index” are necessary to identify the broken clusters. But these two variables are missing in the reconstruction of 2016 data to save space
  - Check how larger the DAOD_IDPIXLUMIFile would be after including these two variables
    - Working on 21.0 which is dedicated to 2017 data
    - Adding "eta_pixel_index" and "phi_pixel_index" has lead to 9.1% increase of the DAOD_IDPIXLUMIFile
  - Ongoing: “Flag_edge” “Flag_broken” → reduce space occupancy

Need to do

- "afterglow" exponentially falling?
  - Run 276073 has several empty bunch crossings.
  - Separate study of clusters from "afterglow" (BCID after the filled BCID)

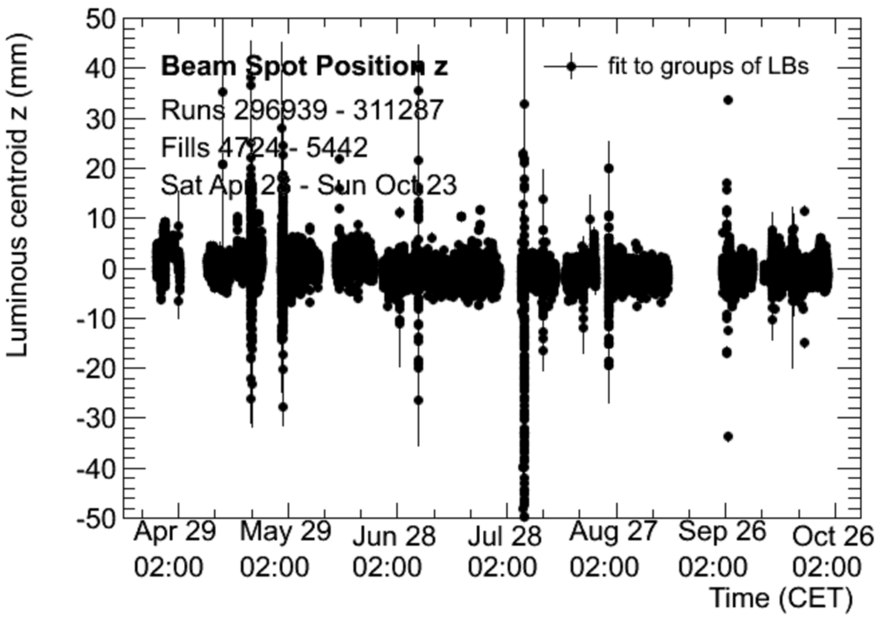
- Tail of cluster length even after filtering out on-edge clusters and broken ones

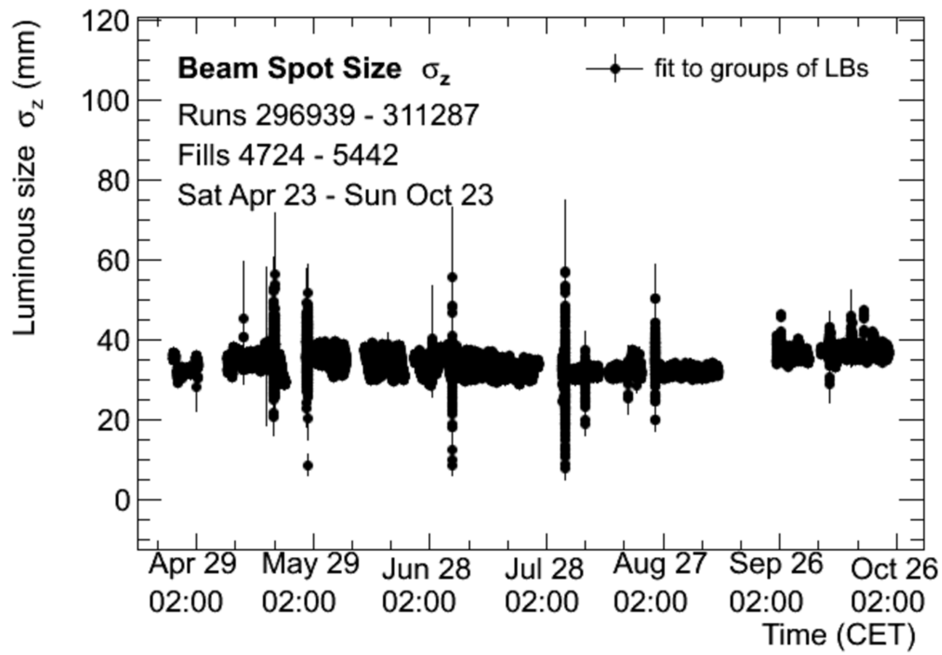


- Could the MC-derived template of secondaries describe the real data?
- Could the fraction of secondaries and "afterglow" be well determined?

Back up

Data2016 13TeV

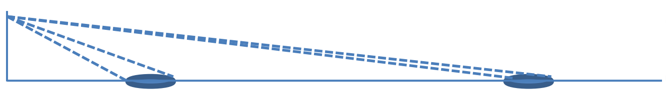


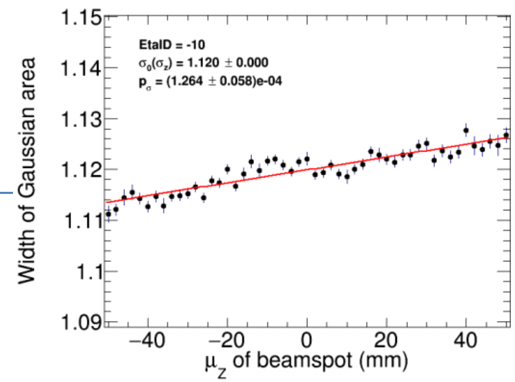


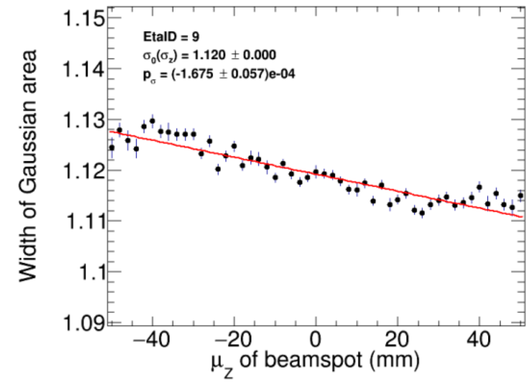
Fix the Gaussian parameters by the fit to clusters from primary particles?

$\sigma_z = 33\text{mm}, \mu_z = -50, -48, -46 \ldots .50mm$

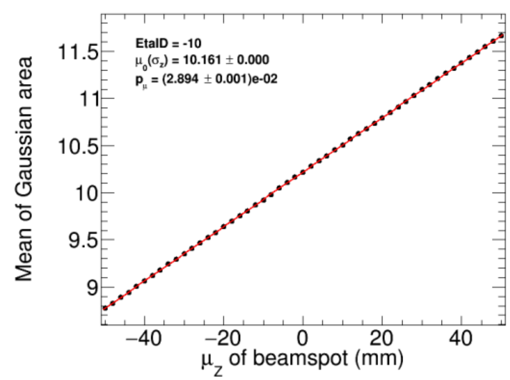
- Width of area (σ_A) depends on both the location and width of beamspot: $\boldsymbol{\sigma_A = \sigma_0(\sigma_z) + p_\sigma * (\mu_z + 2)}$
  - $\sigma_0(\sigma_z)$ is only related to the beamspot width (σ_z)
  - σ_A also depends on the beamspot location (μ_z) because of the different acceptance

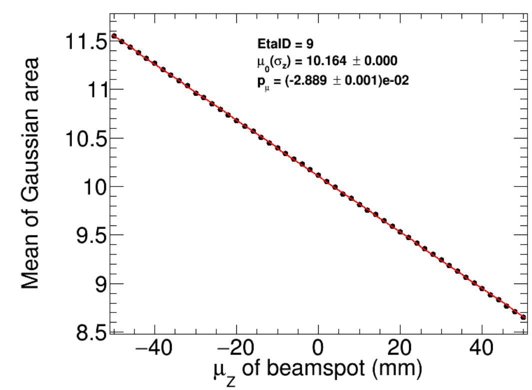






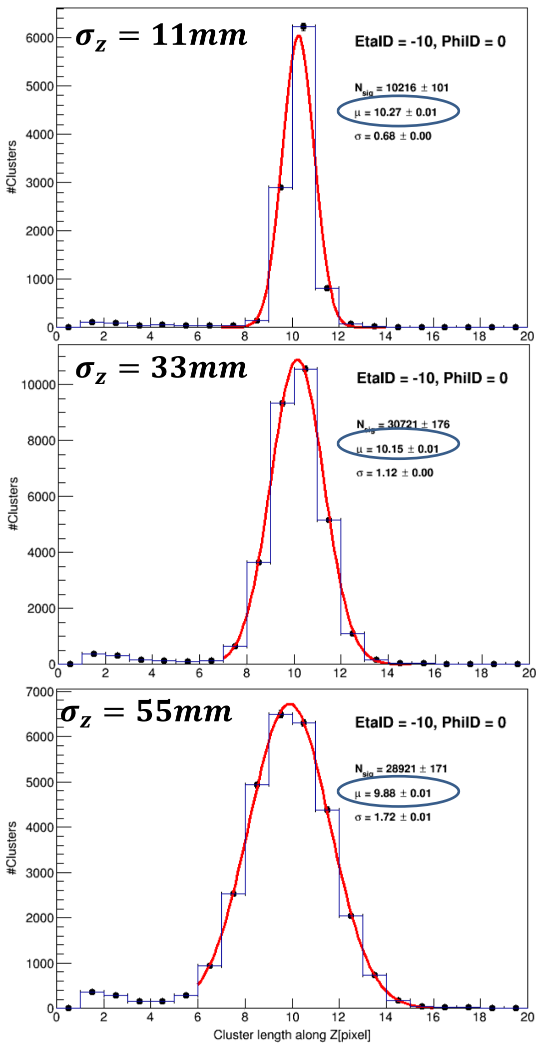
- Mean of area depends on both the location and width of beamspot: $\boldsymbol{\mu_A = \mu_0(\sigma_z) + p_\mu * (\mu_z + 2)}$
  - μ_0 only depends on the module position? It turns out μ_0 also depends on σ_z (see next page)



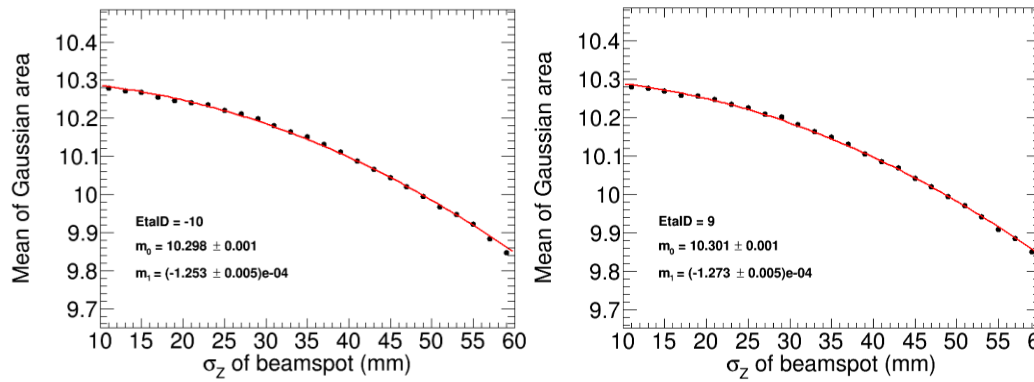


$\mu_z = -2\text{mm}, \sigma_z = 11,13,15 \ldots .59mm$

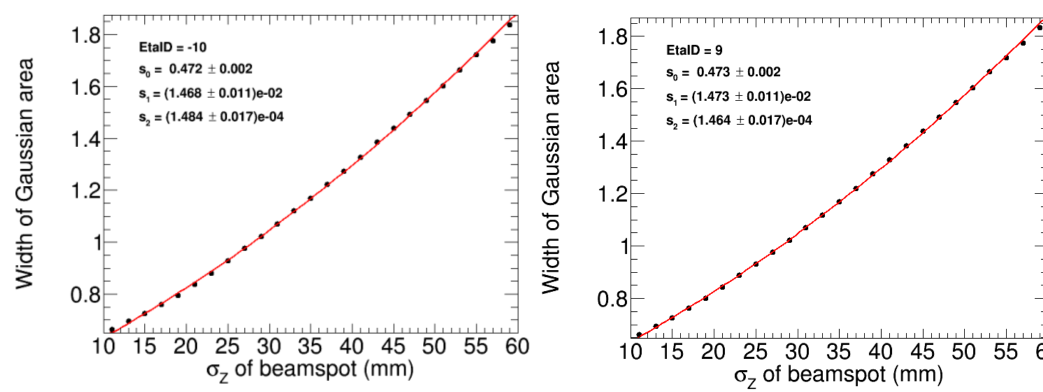
- Mean of the Gaussian area is expected **not** to depend on σ_z, but it actually is.
  - Due to the remaining flat structure on the left?



✓ $\mu_0(\sigma_z) = m_0 + m_1 * \sigma_z^2$



✓ $\sigma_0(\sigma_z) = s_0 + s_1 * \sigma_z + s_2 * \sigma_z^2$



beamspot shape dependence of the Gaussian area shape

- $$\left.\begin{aligned} \sigma_A &= \sigma_0(\sigma_z) + p_\sigma * (\mu_z + 2) \\ \sigma_0(\sigma_z) &= s_0 + s_1 * \sigma_z + s_2 * \sigma_z^2 \end{aligned}\right\} \quad \boldsymbol{\sigma_A = (s_0 + s_1 * \sigma_z + s_2 * \sigma_z^2) + p_\sigma * (\mu_z + 2)}$$

- $$\left.\begin{aligned} \mu_A &= \mu_0 + p_\mu * (\mu_z + 2) \\ \mu_0 &= m_0 + m_1 * \sigma_z^2 \end{aligned}\right\} \quad \boldsymbol{\mu_A = \left(m_0 + m_1 * \sigma_z^2\right) + p_\mu * (\mu_z + 2)}$$

- How to determine the parameters has been shown in the fits in last two pages
  - μ_A and σ_A have been averaged over all modules in the same eta ring
  - The parameters are different for different eta rings (refer to the fits in following pages). The parameters of the symmetric eta rings have been averaged.